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Updated parameters for RHIC head-on beam-beam compensation with electron lenses

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The electron lenses have been proposed for the head-on beam-beam interaction effect compensation in the Relastivistic Heavy Ion Collider (RHIC). The physics numerical simulations and the engeering design of the RHIC electron lens are making progresses. In this note, we update the proton and electron beam parameters and give the latest the layout of the elens installation.

1 Accommodations of RHIC e-lenes

For the RHIC polarized proton run, the two proton beams collide at IP6 and IP8. The proton in the Blue ring circulates clockwise, while the proton beam in the Yellow ring circulates anti-clockwise. In our current design, the e-lenses for the RHIC head-on beam-beam compensations are put close to IP10. Fig. 1 shows the layout of the RHIC ring.

Two e-lenses are needed for the RHIC head-on beam-beam compensation, one for the Blue ring and another one for the Yellow ring. The e-lens for the Blue ring is named BEL, and the e-lens for the Yellow ring is named YEL. In the current design, they are asssumed 2-meter long. They are symmetrically placed 1.5 meter away from IP10. The two proton beams are separated vertically. The maximum separation can be 10mm. The radius of the beam pipe in IR 10 is about 60mm. Fig. 2 shows the installation of the RHIC e-lenses around IP10.

The electron beams are guided into the e-lenses from DX magnet side and dumped in the IP10 side. The beam of the Blue ring interacts with the elctron beam in the BEL. And the beam of the Yellow ring interacts with the electron beam in the YEL.

2 Proton beam paramters

Tab. 1 lists the beam and optics parameters for the proton beams in the following simulations.

The collison energy is 250 GeV. The bunch intensity is chosen to be $N_p = 2.0 \times 10^{11}$. The two proton beams collides only at IP6 and IP8. The beta functions at the IP6 and IP8 are $\beta^* = 0.5$ m. The beta functions at IP10 is set to 20m. The beta functions at the other interactions points (IP2, IP4, IP10), are 10m.

In the beginning of store, the rms emitance is 2.5mm.mrad and the the proton beam size at IP10 is about 0.43mm. In the end of store, the rms emitance is 4.16mm.mrad and the proton beam size at IP10 is about 0.56mm.

For the simulation study, the working point of the proton beam is chosen as $(28.695, 29.685)$. The linear chromaticities are set to $Q'_{x,y} = +1$. The multipole field errors in the triplet quadrupoles and separation dipole magnets in the IRs are included.

The 95% longitudinal emittance for the proton beam is assumed to be 1.0 eV.second. The total rf voltage is 300KV. The rms momentum spread of the proton beam is $\delta_{rms} = 0.1414 \times 10^{-3}$, the rms bunch length of the proton beam is about $\sigma_l = 0.4454$m.

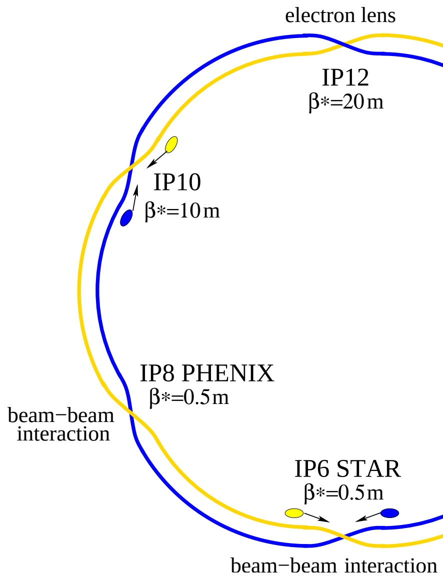

Figure 1: Layout for the simulation.

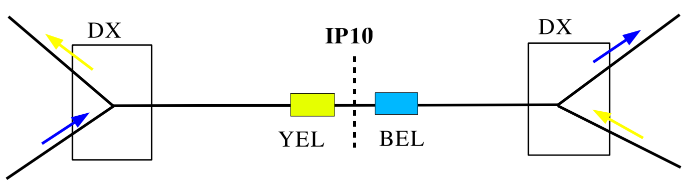

Figure 2: RHIC e-lenses at IP10.

Table 1: Parameters for the proton beams

quantity	unit	value
lattice		
ring circumference	m	3833.8451
energy	GeV	250
relativistic γ	-	266
beam-beam collision points	-	IP6, IP8
beam-beam compensation point	-	IP10
$\beta^*_{x,y}$ at IP6 and IP8	m	0.5
$\beta^e_{x,y}$ at IP10	m	20
$\beta^*_{x,y}$ at all other IPs	m	10
proton beam		
particles per bunch N_p	-	2×10^{11}
normalized transverse rms emittance $\epsilon_{x,y}$	mm mrad	2.5
transverse rms beam size at collision points $\sigma^*_{x,y}$	mm	0.068
transverse rms beam size at e-lens $\sigma^e_{x,y}$	mm	0.430
transverse tunes (Q_x, Q_y)	-	$(28.695, 29.685)$
chromaticities (ξ_x, ξ_y)	-	$(1, 1)$
beam-beam parameter per IP $\xi_{\mathrm{p}\to\mathrm{p}}$	-	-0.01
longitudinal parameters		
harmonic number	-	360
rf cavity voltage	KV	300
longitudinal emittance	eV s	0.1
rms momentum spread	-	0.1414×10^{-3}
rms bunch length	m	0.4454

Table 2: Parameters of RHIC e-lenses.

quantity	symbol	unit	value
electron kinetic energy	K_e	keV	5
electron speed	$\beta_e c$	...	0.14c
electron transverse rms size	σ_e	mm	0.433
effective e-lens length	L_{elens}	m	2.0
total electron particles in e-lens	N_e	-	3.5 $\times 10^{11}$
electron beam current	I_e	A	1.2

3 E-lens paramters

Tab. 2 summarizes the nominal parameters for the RHIC e-lenses.

In the current RHIC e-lens design, the interation region of the proton and electron beams are 2-meter long.The electron beam is supposed to be a DC beam and has a round Gaussian transverse profile. The kinetic energy of the eletrons is $E_k = 5$KeV. Therefore, for the full head-on beam-beam compensation, the number of electrons in the e-lens is 3.5×10^{11}, that gives the electron beam current about 1.2A.

For the head-on beam-beam compensation, the electron beam should have the same transverse sizes as the proton beam in the e-lens. In the current design, we chose the rms electron beam size to be 0.56mm, which is the beam size of the proton beam in the end of store.

Superconducting solendoid is needed to regulate the electron motion in the e-lenses. To cancel their effect on the betatron coupling, the direction of the magnet fields in the two solenoids should be opposite.

References

[1] Y. Luo and W. Fischer, "Outline of using an electron lens for the RHIC head-on beam-beam compensation", BNL C-AD AP Note 286.

[2] RHIC e-lens meetings can be found at

http://www.cadops.bnl.gov/AP/BeamBeam/2007_elens_meeting.html.